Protective Clothing Based on Permselective Membrane and Carbon Adsorption

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Introduction

Over the next three decades, the Department of Energy (DOE) faces an enormous decontamination and decommissioning task as facilities associated with research, development, and production of atomic weapons are closed. This task is complex and expensive because many sites are contaminated with a variety of hazardous compounds ranging from asbestos, mercury and other heavy metals, to toxic organic compounds, such as polychlorinated biphenyls (PCBs) and chlorinated solvents, and radioactive metals and salts. Because of the hazards of exposure to these materials, workers must frequently wear completely encapsulating protective garments. These garments are impermeable to particulates, aerosols, and organic vapors and provide good protection from toxic contaminants. However, the garments are heavy, time consuming to don and remove, and most importantly, are impermeable to water vapor. Since the garments are water vapor impermeable, it is very difficult for body heat to escape. As a result, workers easily become heat stressed and must rest frequently. DOE is therefore interested in chemically protective clothing which allows heat removal and funds several projects in this area, including a project at MTR.

The goal of this project is to develop chemical protective clothing for use by DOE decontamination and decommissioning workers that will increase worker productivity—because it is cooler and more comfortable than conventional protective clothing—while maintaining protection against chemical liquids and vapors.

Work Description

The fabric is based on a permselective membrane that is permeable to water but relatively impermeable to toxic organic vapors. In the first phase of the project, the fabric properties were improved by modifying both the materials and the preparation procedure used to form the membrane. Subsequently, production of the fabric was scaled up to use commercial-scale production machinery. A small number of prototype suits were made, and a preliminary suit evaluation was conducted.

Two fabrics were developed, designated MTR-1 and MTR-2. Figure 1 shows a diagram of the MTR-2 material, which is a laminate of two identical, composite fabrics that we refer to as the permselective fabric. This permselective fabric is manufactured by casting a sorptive layer of zeolite-loaded poly(vinylidene fluoride) onto a woven support fabric. Subsequently, a thin permselective polymer layer of polyvinyl alcohol is solution-coated onto the sorbent layer. Then two lengths of the permselective fabric are laminated by joining the permselective layers, leaving the woven support fabric on both outer surfaces of the resulting protective fabric (or laminated fabric). The other fabric, MTR-1, consists of one permselective fabric layer laminated to a nonwoven fabric, which forms the inside surface of the resulting fabric. Thus, the thinner MTR-1 fabric is more comfortable but less protective than the MTR-2 fabric. Both fabrics combine moderate chemical permeation resistance, moderate water transmission, and good physical properties and durability.

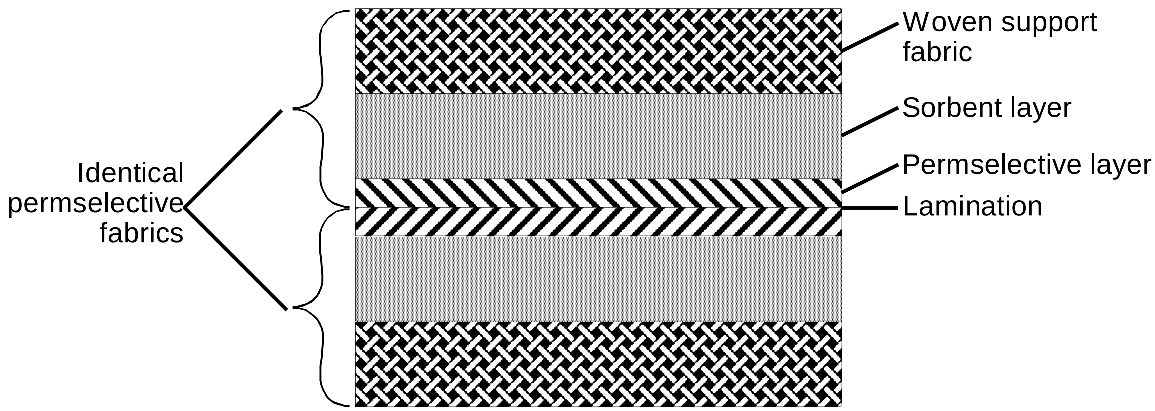

Figure 1. Structure of MTR-2 protective clothing fabric.

Results

The fabrics produced during this project are a significant advancement in state-of-the-art protective fabrics. No currently available fabrics combine protection against vapor and liquid chemical hazards while minimizing the potential for heat stress by allowing water vapor (perspiration) to permeate the fabric. A comparison with commercially available fabrics is given in Table 1. The fabrics developed in this project meet the water transmission rate goals (greater than 800 $g/m^2 \cdot day$) and provide chemical protection equivalent to currently used non-water-vapor-permeable (occlusive) chemical protective suits. These results were achieved in a practical fabric that is strong, durable, flexible, lightweight, and easy to manufacture into a suit. A cost-benefit calculation, based on the improvement in worker productivity achieved with MTR water-vapor-permeable suits over a conventional occlusive suit, shows that the MTR suits are cost effective only if used for two days or more. However, small and achievable improvement in the fabric properties and expected reductions in production cost as the process is scaled up would make MTR's water-vapor-permeable suits cost effective even when exchanged daily.

Table 1. Properties of MTR and Commercially Available Protective Fabrics

Property	MTR-1	MTR-2	Tyvek	Saranex-Coated Tyvek	Barricade
Chemical Permeation (dichloromethane) ($\mu g/cm^2 \cdot min$)	440	165	high	120	<0.1
Water Vapor Transmission (MVTR) ($g/m^2 \cdot day$)	800 - 1,200	800 - 1,300	1,000 - 2,000	0	0
Thickness (mils)	10	8	8	10	21
Weight (oz/sq yd)	6	6	1	4	5

Conclusions and Discussion

We conclude that the fabrics produced during this project are a significant advancement in state-of-the-art protective fabrics. No currently available fabric combines protection against vapor as well as liquid chemical hazards while reducing the potential for heat stress by allowing water vapor to permeate the fabric. MTR's fabrics achieved the water vapor transmission rate goals (greater than 800 $g/m^2 \cdot day$) and provided chemical protection similar to currently used non-water-vapor-permeable chemical protective suits. Table 2 lists six performance criteria for chemical protective clothing and compares the performance of the MTR suit with that of currently available suits.

Table 2. Protective Fabric Performance Criteria and a Comparison Between MTR Suits with Commercially Available Suits

1. Water vapor transmission rate Heat stress measurements indicate that a worker wearing the MTR suit will be measurably cooler than if wearing a conventional Saran/Tyvek suit.
2. Chemical permeation rate Dichloromethane breakthrough time and permeation rate of the MTR suit are comparable to Saran-coated Tyvek fabric (< 5 min; ~ 100 $\mu g/cm^2 \cdot min$).
3. Fabric durability Suits have flexibility and durability comparable to current chemical protective clothing.
4. Fabric manufacturability Enough full-scale rolls of fabric (1 m wide × 100 m long) have been produced to make 10 to 20 prototype suits
5. Suit manufacturability Twelve suits for laboratory tests have been produced, using standard procedures.
6. Cost effectiveness of suit An economic analysis shows that the savings due to higher worker productivity are greater than the price difference between MTR and conventional suits.

MTR has entered into an agreement with the Kimberly-Clark Corporation under which Kimberly-Clark will evaluate whether the protective fabrics developed by MTR can be manufactured on their existing production equipment and whether cost reductions are feasible. Kimberly-Clark and MTR expect to produce the next generation of suits in the middle of 1998 and to carry out an evaluation at the International Union of Operating Engineers test facility in August-September 1998.